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Geomechanical in situ testing of fault reactivation in argillite repositories

Jens T. Birkholzer[1], **Yves Guglielmi**[1], **and Christophe Nussbaum**[2]

[1]Energy Geosciences Division, Lawrence Berkeley National Laboratory, Berkeley, CA, USA
[2]Swisstopo, Wabern, Switzerland

Correspondence: Jens T. Birkholzer (jtbirkholzer@lbl.gov)

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Abstract. Pressurization of natural faults as a result of repository-induced effects can lead to their reactivation and permeability generation in case such features are present near disposal tunnels. Potential driving forces for such pressurization are the temperature increase caused by heat-producing high-level radioactive waste and the generation of hydrogen and other gases due to corrosion of engineered materials. We are primarily concerned about pressurization and fault activation in host rocks and faults that have very low natural permeability for pore pressure increases to dissipate, such as the argillite rocks currently investigated in Switzerland, France and other countries. This presentation discusses a series of in situ experiments of fault activation by fluid injection conducted in the argillite rock (Opalinus clay) at the Mont Terri underground research laboratory in Switzerland. A multi-model monitoring test bed was installed at Mont Terri that includes distributed fiber optics for strain, temperature, and acoustics; local fault pore pressure and three-dimensional displacement sensors; active seismic imaging; and passive seismic monitoring. The fault experiments (and their subsequent analysis via hydromechanical modeling) provide a new fundamental understanding of the coupling between pore pressure, fault deformation and permeability generation as a function of time and allow exploring how seismic and aseismic events may impact the integrity of faulted argillite host rock.

Our experimental observations demonstrate that significant flow (and transport) can occur along the initially impermeable argillite fault when rupture is activated. However, the fault permeability decreases to almost its pre-activation value when fluid injection ceases and fluid pressure drops. Dilatant slip on the fault plane alone does not explain the observed increase in fault permeability; pressure-induced fault opening also plays a role, favored by the softness of the shale along with the fact that the structure of the fault zone prevents fluids from diffusing into the adjacent damage zone. Rupture initiation and permeability generation is initially aseismic, associated only with an increase in noise level and emerging tremors. Micro-earthquakes are initiated later in the experiments and typically occur away from the fluid-pressurized area. Hydromechanical models show that stress transferred from the initial aseismic deformation can build up to stress criticality and later induce seismic rupture.

After presenting the experimental results, we will close the presentation with an outlook to future experimental campaigns using the fault test bed at Mont Terri. We are currently planning a controlled thermal stimulation of the fault, where instead of fluid injection as a trigger mechanism we will heat up the nearby rock volume and measure potential effects on fault stability. Lessons learned from our past and future experiments will help inform the safety assessment of geologic disposal in argillite host rock.

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